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TUNABLE OPTICAL SOURCES

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Contract No. DAHC-04-68-C-0048

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R. L. Herbst	Research Assistant
J. F. Young	Research Associate

I. RESEARCH OBJECTIVES

The purpose of this contract is to conduct investigations of materials and techniques leading to the realization of tunable coherent light sources. During this period work ~~has~~ proceeded on materials and laser pump sources aimed at achieving the above objectives.

II. CUMULATIVE PROGRESS TO DATE

1. We have investigated the optical properties of CdS , CdSe , proustite, and $LiIO_3$ and have proposed CdSe as a material useful for infrared parametric oscillators.

2. We have developed and published a paper describing a $LiNbO_3$ testing technique based on birefringent measurements and second harmonic testing. The technique allows high optical quality $LiNbO_3$ crystals to be tested for nonlinear optical properties.

3. We have investigated the striation problem in $Ba_2NaNb_5O_{15}$ crystals by a new optical technique.

4. We have proposed and demonstrated laser oscillation on the .946μ line of Nd^{3+}:YAG lasers and have demonstrated efficient second harmonic generation of that line.

III. INVESTIGATIONS BEING UNDERTAKEN

A. <u>CO Laser Development</u> (R. L. Byer and R. L. Herbst)

Since the last report oscillation has been observed near 5.3μ from the CO laser operating at $77^{\circ}K$. Continuous power outputs of up to 4 watts

were obtained for short operating times. The laser was also operated on a pulsed basis with pulse widths from .1 to 1 milliseconds and repetition rates of 20 pulses per second. It was noticed that during pulsed operation the operating discharge current for optimum output power drifts with time. This indicates a changing plasma impedance and is probably due to the absorption of gases on the discharge tube wall during pulse-off times and the rapid evolution of gas during pulse-on times. This makes operation difficult and a satisfactory solution has not yet been reached. Synchronous Q-switching the CO laser will be tried soon.

B. CdSe Material Study

In the previous report we gave the indices of refraction and birefringence of CdSe in the infrared region of the spectrum. The results were used to calculate an angle tuned parametric oscillator tuning curve which is shown in Fig. 1. Due to the lack of sufficient birefringence the oscillator does not tune to the degenerate point. We have investigated this problem and have suggested that a lower crystal temperature at near liquid nitrogen may solve the problem. However, to date we have not been able to confirm whether CdSe does 90° phase match at liquid nitrogen temperatures for the degenerate oscillator.

Since the last report we have discovered that pressure tuning of the indices of refraction will allow the CdSe birefringence to be increased enough to reach the degenerate point. The data shown in Fig. 2 is from M. Grynberg, "Influence of the Uniaxial Stress on the Optical Properties of CdSe Single Crystals". It shows that an increase in birefringence of .002 can be reached by applying pressure along a direction perpendicular to the

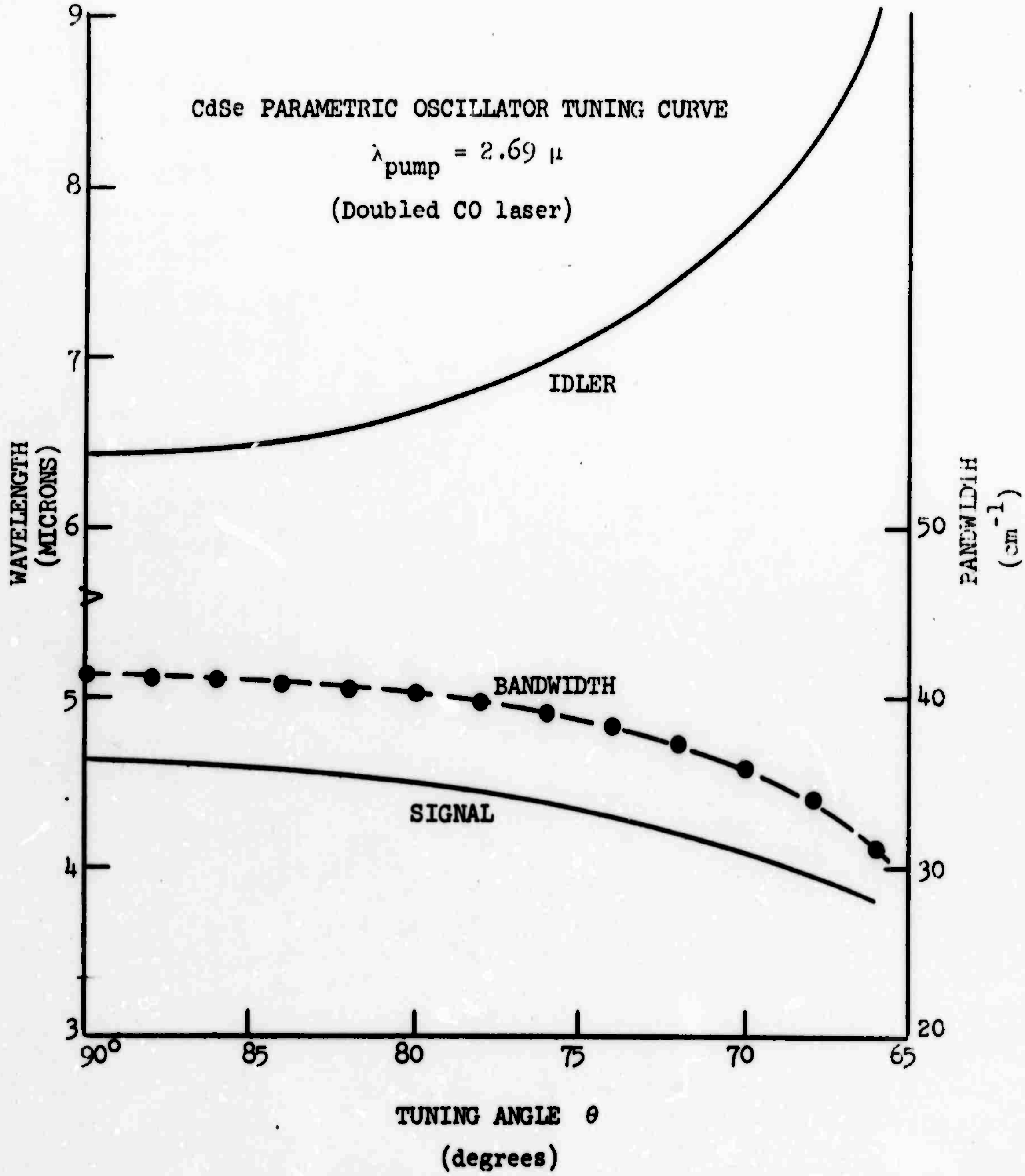


FIG. 1--Parametric oscillator tuning curve for CdSe pumped with doubled CO at 2.69 μ.

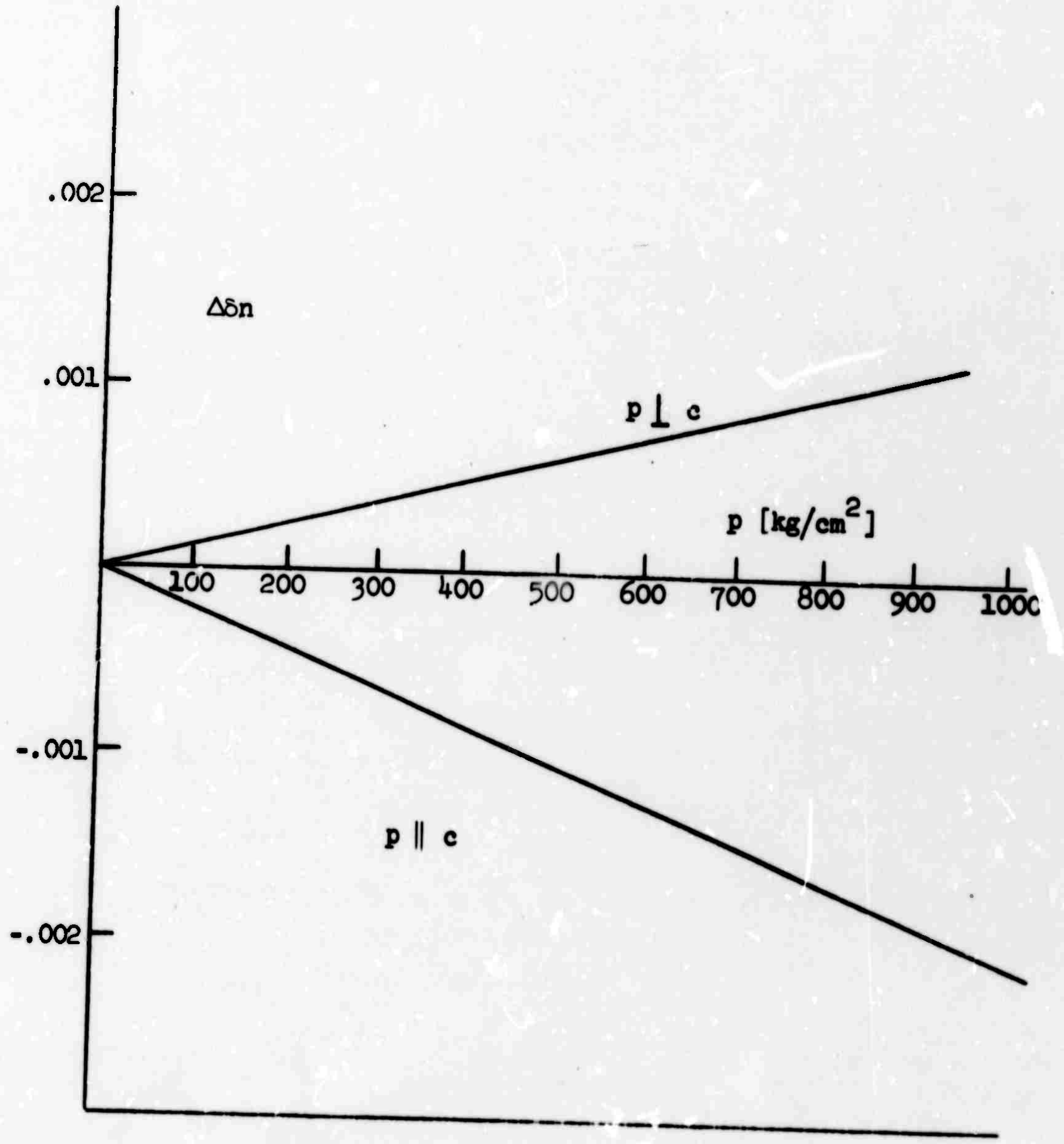


FIG. 2--Change in CdSe birefringence vs applied pressure.

crystal c-axis of about 1600 kg/cm^2. This pressure is possible to maintain, in practice, and thus will allow 90° phased matched second harmonic generation to be reached for the CO laser and for the degenerate oscillation point to be tuned through via pressure for the CdSe oscillator. We are presently verifying the above pressure data for our CdSe crystal. If it proves to be valid, pressure tuning curves for the oscillator will then be calculated.

C. Progress on the Proposed CdSe Parametric Oscillator

At present the main effort lies in obtaining a suitable pump for the parametric oscillator at 2.7μ. As stated above, progress is being made with the development of the CO laser. It holds promise as a pump source because of its high efficiency, single frequency operation and relatively long Q-switched pulse lengths which are needed for oscillator buildup time.

However, since the oscillator itself is ready to construct, having simply two mirrors and a 2 cm long CdSe crystal, an alternate pump source is being investigated.

As an alternative to the internal second harmonic generation of the CO laser as a pump source for the CdSe oscillator, it is also possible to use a Nd:YAG pumped $LiNbO_3$ oscillator for the pump source. The operation of this pump is as follows.

The Q-switched YAG laser will be operating at $.946\mu$. The $LiNbO_3$ crystal will be used in the internal oscillator configuration with crystal placed inside the YAG laser cavity. With the crystal at $200^\circ C$ and cut at 55° to the c-axis, signal and idler frequencies will occur at 1.4 and 2.75 microns respectively. Resonating only the signal frequency

at 1.4μ it is expected that at least 3 kW of power will be available at the 2.75μ idler frequency. This then could be used as a pump source for the CdSe oscillator.

Since the $LiNbO_3$ parametric oscillator is internal to the YAG cavity it is expected that very high efficiency will be reached. Also, the oscillator acts as a nonlinear element within the cavity and thus will provide pulse stretching similar to internal second harmonic generation. We are presently in the process of developing this alternative pump source to the CO laser while continuing our work to improve the CO laser.

The CdSe oscillator has been designed and two of the proposed configurations are shown in Figs. 3(a) and 3(b). The straightforward 5 cm confocal cavity with straight through pump, signal, and idler waves should allow for the demonstration of the oscillator. In this configuration, the mirrors are high reflecting at the signal wavelength of 4.7μ and are transmitting at both the pump and idler wavelengths of 2.7μ and 6.6μ respectively. The crystal is anti-reflection coated at the signal. The confocal cavity allows for very easy alignment at a slight increase in threshold. The advantages of this design are ease in alignment, simple mirror design, and 90° phase matching without pressure or an oven for temperature control. The disadvantage is lack of any real tuning range.

The oscillator design shown in (b) of Fig. 3 overcomes the disadvantage of the above oscillator but at an increase in complexity. The crystal is cut at Brewster angle and the signal is resonated with broadband very highly reflecting gold mirrors. Thus the signal can be tuned over its entire range with very low loss. To get the pump in and the idler out, advantage is taken of

the type-two phasematching polarizations, where the pump and the idler are both polarized orthogonal to the signal. This allows the pump to be brought in via a reflection from the Brewster surface with a 50% reflection coefficient. The idler is coupled out by a similar reflection. The disadvantage of the previous oscillator of narrow tuning range is now overcome. Tuning may be accomplished for this design by pressure or angle or a combination of both.

Calculations have been made for the single resonant CdSe oscillator with a 5 cm confocal resonator. For a 90° cut crystal and a pump source of 2.75μ the signal and idler frequencies will occur at 4.7μ and 6.6μ respectively. The threshold pump power is given by

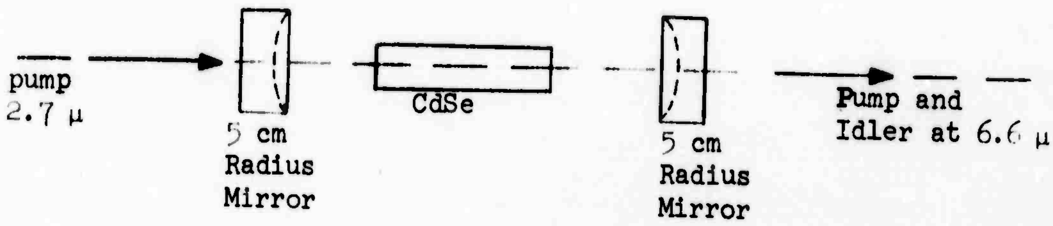
$$P_p = \frac{\alpha_s \pi \omega_0^2}{\omega_0^2 \eta^3 d^2 L^2 (1-\delta^2)^2}$$

where α_s is the loss at the signal frequency for the signal only resonant case, ω_0^2 is the confocal spot size at the degenerate frequency, and ω_0 is the degenerate frequency. δ^2 accounts for operation off degeneracy where

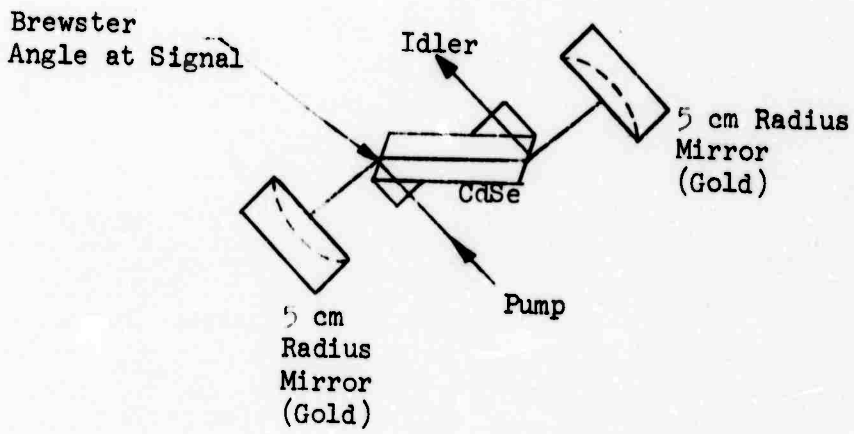
$$\delta = \frac{2\lambda_{pump} - \lambda_{signal}}{\lambda_{signal}} .$$

Using $\alpha_s = 10^{-2}$ and an $L = 1$ cm we get $P_p = 375$ watts , which is well within the range of the $LiNbO_3$ oscillator pump source of about 3 kW .

We have ordered the oscillator components and are now constructing the $LiNbO_3$ pump source. We have been able to obtain CdSe crystals up to 2 cm in length which lowers our threshold from 375 watts by a factor of four to less than 100 watts . Also, the longer crystal decreases the bandwidth to about 20 cm^{-1} at our operating frequencies.



(a)



(b)

FIG. 3--(a) Collinear CdSe oscillator with signal resonant only
(b) Brewster angle cut CdSe for wide band tuning.

D. <u>Qualtiy Testing of $LiNbO_3$ Crystals</u>.

The above paper has been written to include a discussion of crystal growth parameters and was submitted for publication. It is to appear in th- May issue of the Journal of Applied Physics, titled "Growth of High Quality $LiNbO_3$ Crystal from the Congruent Melt," by R. L. Byer, J. F. Young, and R. Feigelson.

E. <u>Constant Dispersion Rotating Grating CO_2 Q-Switch</u>

A note to the editor with the above title is being prepared which describes our constant dispersion grating Q-switch. This Q-switch allows the CO_2 or CO laser to be switched on a single rotational line rather than scanning sequentially through all the rotational lines. This Q-switch device was described in the previous report.

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